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THE EFFECTS OF AIR POLLUTION

Public Health Service
Washington, D. C.

1966

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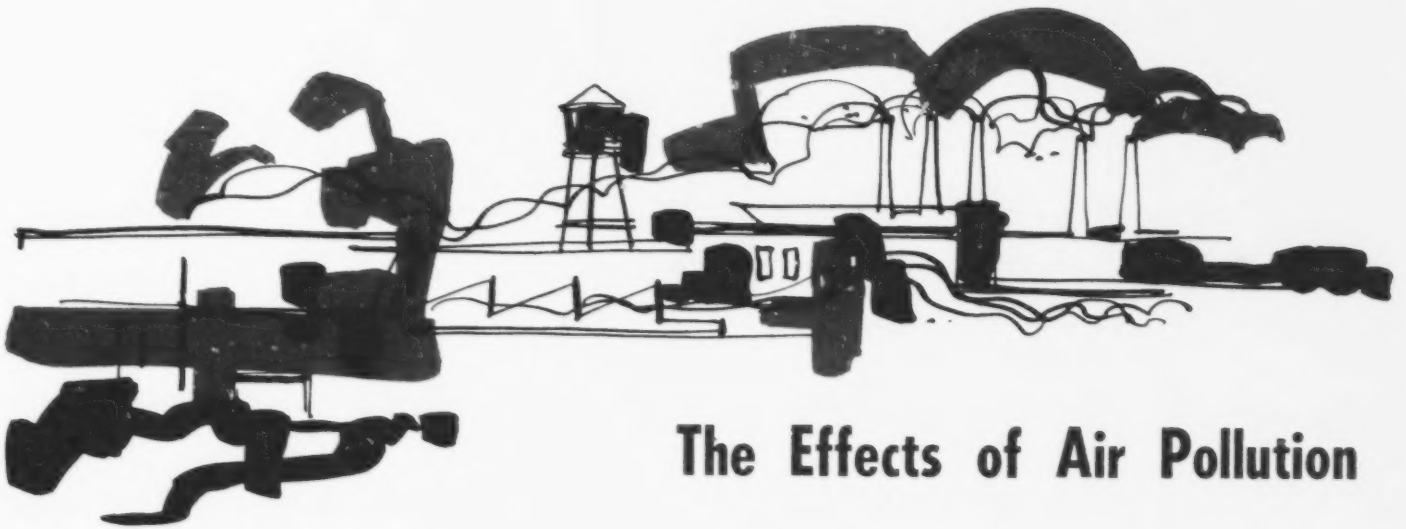

The Effects of Air Pollution

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Washington, D.C. 20201
Division of Air Pollution
1966

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Public Health Service Publication No. 1556

"Some segments of our population are interested in air pollution because it soils the paint on their homes and interferes with the proper growth of certain of their ornamental plants and shrubs. I welcome their support.

"Other people ask for the abatement of air pollution primarily because they are tired of brushing soot off the sill every time they open a window for a breath of more-or-less fresh air.

"There are yet others who seek an end to air pollution because their citrus groves will not flourish or their cattle will not grow properly in an atmosphere contaminated with certain types of pollutants.

"Some seek an end to pollution because it interferes with the proper performance of their professions. These are represented by such diverse groups as city planners, airline pilots, farmers, and manufacturers—particularly those who need clean air to produce the products they market.

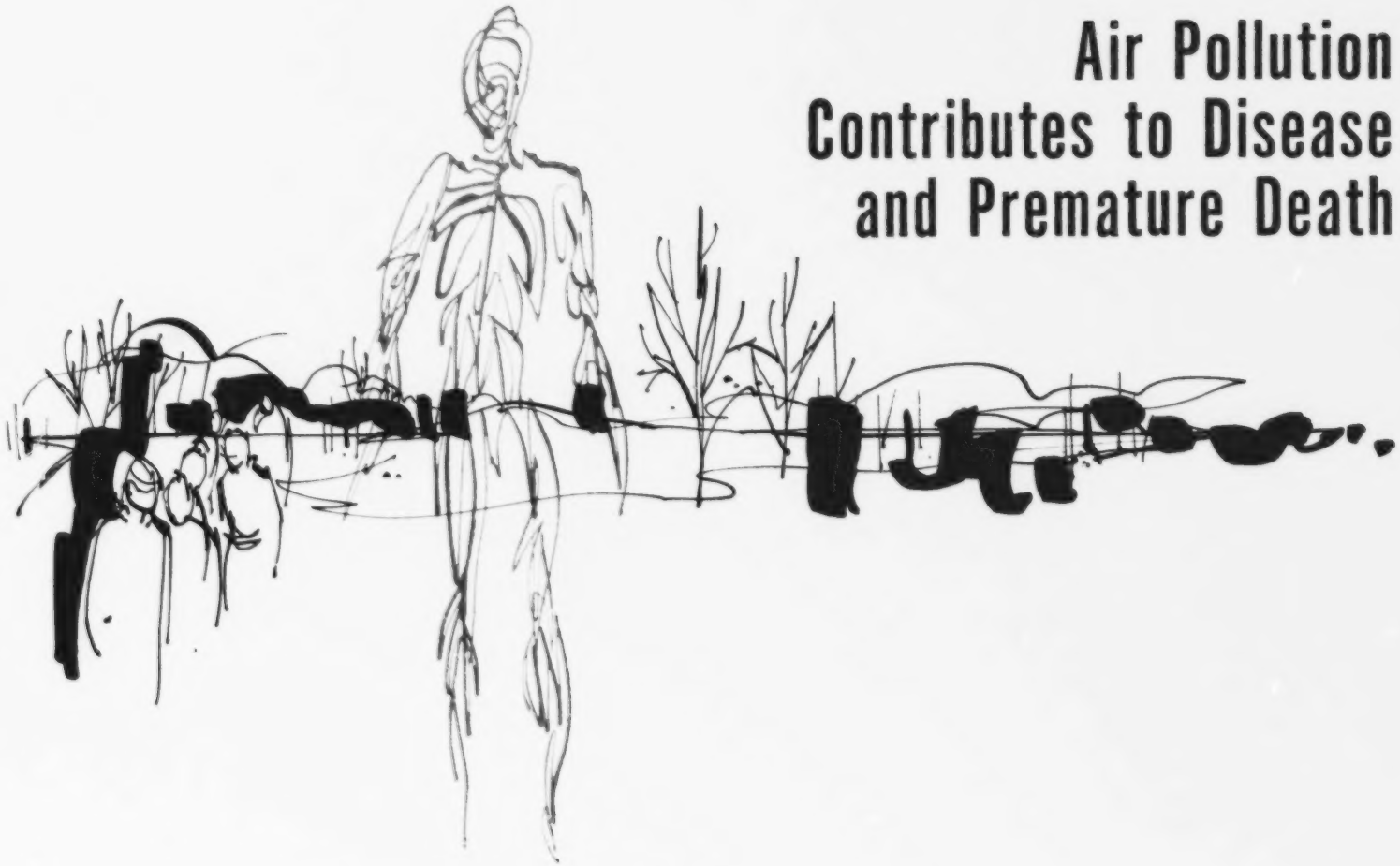
"There are many who seek an end to air pollution because they don't like the smells that assail them where they live or work; and many who are chagrined because the mountains or the forest or the other aesthetic delights that they enjoyed as children are now obscured by a blanket of smog on too many days of the year.

"All of these and others have good reasons for wanting to see the myriad sources of air pollution abated. But all of them I believe, would agree that the primary reason they favor control is that air pollution threatens human health. The threat to health, in my opinion, constitutes the primary impulse for the control of air pollution in the United States."

William H. Stewart, M.D.
Surgeon General, United States Public Health Service

From the remarks of Surgeon General Stewart at the annual meeting of the Air Pollution Control Association, June 1966.

Air Pollution Contributes to Disease and Premature Death



Unless gas masks are to become a habitual part of our dress, we must breathe the air as it comes to us, polluted or not. For most of us, more often than not the air is polluted with a host of gases and particles which we pump into our lungs and swallow into our stomachs. Some pollutants sting our eyes and throats, and others affront our noses. Still others find their way into our bloodstream, where they travel up and down the body, working their toxic ways as they go.

It is in our respiratory system, and particularly in our lungs, that we are most vulnerable to air pollution. Life depends on the steady supply of oxygen from the lungs to the blood, and the steady removal of carbon dioxide from the blood by the lungs. These gases are transferred through hundreds of tiny balloons whose skins are one ten thousandth of an inch thick. This delicate tissue, if spread flat, would cover a tennis court, and when we are born we have many more balloons than we need for breathing. But one of the cumulative effects of air pollution (along with smoking and disease) is the progressive destruction of these balloons, and as we grow older, we lose some of our lung reserve. Unfortunately, for many of us, we are not aware of the loss until much of our reserve is gone. And the damage is irreparable.

The Disasters

The most dramatic evidence of the effects of air pollution on human beings lies in the disasters that have overtaken both large and small communities.

In December 1930, a thick and stagnant fog enveloped a heavily industrialized section of the Meuse Valley, Belgium. By the third day many persons developed throat irritation, hoarseness, cough, and breathlessness. Some were nauseated. Some died. The elderly and those already ill with respiratory disease or heart disease were most vulnerable.

In October 1948, a similar fog blanketed the small industrial town of Donora, Pennsylvania. Before an afternon rain cleared the fog away four days later, 6000 persons of the town's 14,000 came down with one or more of an assortment of ills—cough, sore throat, chest constriction, headache, a burning sensation of the eyes, nasal discharge, and vomiting. Twenty persons died during a period of the year when Donora could expect only two to die. Those present remarked on the heaviness of the fog, and on the intensity of the familiar odor of sulfur dioxide whose source was largely in the industrial operations of the town.

At the beginning of December 1952 the city of London went through a four day period of still air during which pollution accumulated in a pea soup fog. Months later a review of mortality statistics revealed that 4,000 excess deaths had occurred in the city during a seven day period that began with the first day of the fog. The illness rate during the period, especially the cardio-respiratory illness rate, increased to more than twice the normal rate for that time of year, and did not return to normal until two to three weeks later. London went through a similar episode in 1962, and the city of New York went through much the same kind of disaster in 1953 and again in 1962.

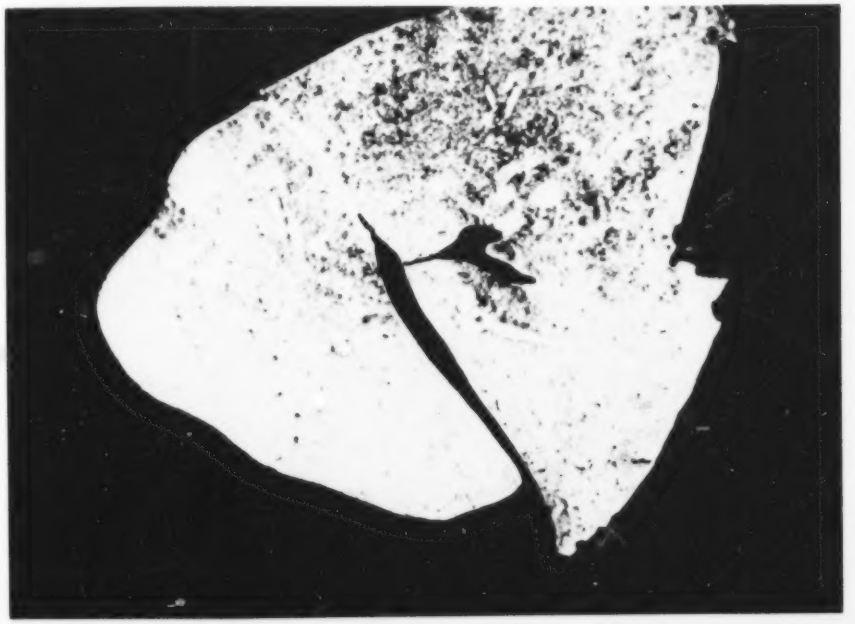
There are other episodes that have been recorded, and some, no doubt, that are unrecorded. All the recorded episodes have in common an abnormal atmospheric condition —the so called temperature inversion — during which a blanket of warm air seals in the airspace upon which a community lives, and prevents dilution and dispersal of its pollutants. Temperature inversions occur frequently in some areas of the United States, and infrequently in others. They occur, however, a considerable number of days a year in virtually every region of the country.

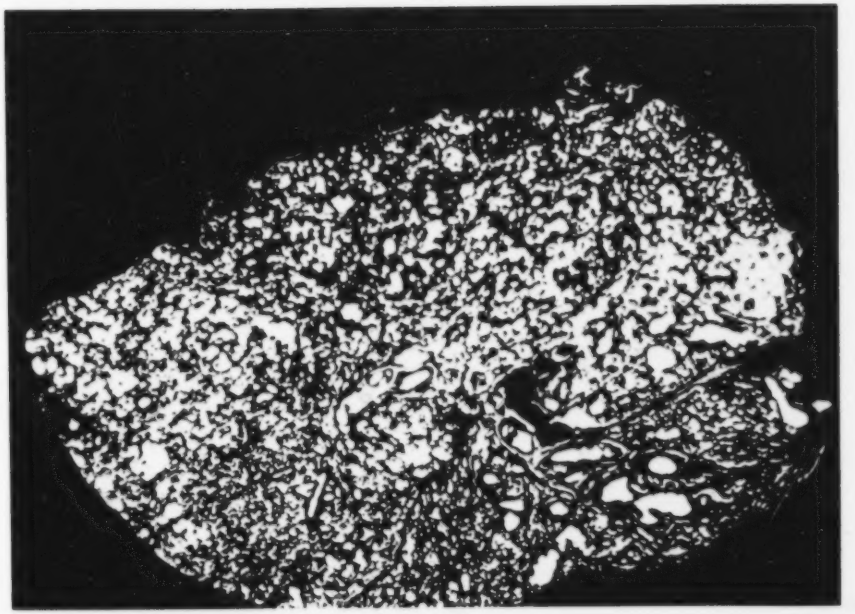
The Diseases

The air pollution disasters are alarming enough, but of even greater concern to those of us who live in polluted air, and that includes most of us, are the long term effects of the air pollution that begins to assail us from the day of our birth. With every breath we take, an increasing percentage of us come a little closer to a diagnosable diseased condition. These ills are mostly diseases of the bronchial tree—from the common cold to lung cancer. But air pollution also irritates the eyes, and some pollutants in the air, like lead, may build up in the body until they reach harmful levels. Others, like carbon monoxide, are not cumulative in their effects, but in high enough concentrations can cause temporary disability, and even death.

Emphysema is a progressive breakdown of air sacs in the lungs usually brought on by chronic infection or irritation of the bronchial tubes, and which progressively diminishes the ability of the lungs to transfer oxygen to the bloodstream and carbon dioxide from it.

Today in this country, emphysema is the fastest growing cause of death. In the 10 year period between 1950 and 1959 deaths among males from emphysema rose from 1.5





per hundred thousand to 8 per hundred thousand. In 1962 more than 12,000 persons died of emphysema in the United States and each month 1,000 more workers are forced prematurely to retire onto Social Security rolls because of the disease.

Studies have demonstrated that emphysema patients improve when they are protected from air pollution. In one study, emphysema patients exposed to photochemical smog expressed subjective relief and showed objective improvement when the air was filtered. The fact that the incidence of

emphysema is greater in our cities than in our rural areas points to air pollution as a contributing factor, as does the fact that deaths from emphysema are twice as high in the city as in the country.

The criteria for diagnosing *chronic bronchitis* have yet to be standardized in this country. In Great Britain, where the criteria are defined as chronic productive cough, nearly 10 percent of all deaths and more than 10 percent of all industrial absences because of illness are attributed to this disease. Using the British criteria one investigation in this country found chronic bronchitis in 21 percent of men 40 to 59 years old. Other studies indicate that 13 to 20 percent of adult males in this country have the disease.

In Great Britain, where more attention has been given to the disease and where more data are available, cigarette smoking and air pollution are accepted as distinct causes of chronic bronchitis. The mortality rate from the disease in Great Britain has been found to vary directly with such air pollution measures as population density, amount of fuel burned, sulfur dioxide levels, settled dust, airborne dust, and decreased visibility. Known sufferers of the disease who were systematically observed showed a worsening of their symptoms on days of higher air pollution.

Chronic constrictive ventilatory disease is a long continued constriction of the air passages that requires extra effort in breathing. Healthy persons may not notice the extra effort, but for those whose lungs or hearts are already functioning marginally, such effort may be unbearable.

Laboratory experimental work with both animals and humans has shown that such irritant pollutants as sulfur oxides, at levels routinely found in our city air, can produce airway constriction, and thus may lead to the chronic disease. And the disease is not confined to the city. In a study of two Pennsylvania towns, each with a population of slightly less than 1,000, and whose environments differed principally in the levels of air pollution, airway resistance was higher in the people living in the town with higher levels of air pollution.

Bronchial asthma is a condition often aggravated by air pollution. However, since the list of stimuli capable of triggering asthmatic attacks is long, it is difficult to define precisely the role of air pollutants. It has long been known that occupational exposure to certain dusts and vapors, including many that are sometimes found in substantial quantities in the air over our cities, can bring about asthmatic attacks. The previously mentioned Donora tragedy provided a striking example of the role of air pollution in aggravating asthma attacks and even

in bringing death to some asthmatics.

A special form of asthma appeared in 1946 among American troops and their dependents living in Yokohama, Japan. The disease later appeared among our troops in Tokyo, and it was given the name *Tokyo-Yokohama asthma*, or *T-Y asthma*. The disease did not yield to the usual asthma specifics; however, patients usually recovered if they were promptly removed from the area upon becoming afflicted. Studies showed that the incidence of the disease and the severity of attacks correlated best with levels of air pollution, which had its origins in the heavily industrialized Kanto Plain, extending between Yokohama and Tokyo.

In New Orleans, epidemic outbreaks of asthma attacks have been associated with certain wind conditions. When the attacks first occurred, they were associated with particulate matter discharged into the air when certain abandoned city dumps spontaneously caught fire underground. Further investigation, however, indicated that other sources of air pollution contributed to the outbreaks.

Many investigations have connected air pollution with the incidence of the *common cold*. A study in a Maryland city of two groups of people who differed, for the most part, only in the amounts of particulate matter they were exposed to, found that the group living in the more polluted section of town had more colds. In a large scale study of absenteeism in industrial plants widely scattered throughout the United States it was found that levels of air pollution correlate with increased frequency of acute infections of the upper respiratory tract. Investigations in Great Britain, Japan, and the Soviet Union have confirmed the American findings.

Experiments in the laboratory have repeatedly shown that animals forced to inhale some of the irritating gases commonly found in community atmospheres are more vulnerable to *pneumonia* organisms than animals not exposed to the gases.

Deaths from *lung cancer* have been increasing rapidly in recent years, and while many factors are probably involved, the striking difference between the urban and rural mortality rate for lung cancer points to one of them — air pollution. The rate in our large metropolitan areas is twice the rural rate, even after full allowance is made for differences in smoking habits. The death rate from lung cancer is apparently directly proportional to city size, and the same can be said, in general, for levels of air pollution.

Four independent studies have shown that longtime residence in countries with different degrees of air pollution was associated with different incidences of lung cancer. In one study, for example, of a Norwegian group that emigrated to America the incidence of lung cancer was halfway between the incidence in Norwegians who stayed at home and the incidence in native Americans. In Norway, where there is much less air pollution, the lung cancer rate is half that of the United States.

Laboratory investigations have provided further clues. In one study, mice that had been sensitized with influenza virus and then exposed to ozonized gasoline (simulated photochemical smog) developed bronchogenic cancer of the type humans develop. In another study, hamsters exposed repeatedly to intratracheal administrations of a particulate form of hydrocarbon that is found much more frequently in city air than in rural air, all developed bronchogenic cancer.

Air Pollution is a Complex Problem

Both the nature and the seriousness of the problem of air pollution can vary from place to place, from season to season, even from hour to hour. Photochemical smog, for example, does not occur at night. In northern parts of the country sulfurous pollution usually is more serious in the cold weather months because we burn more fuel for heating. In southern sections of the country sulfurous pollution may go up in the warm weather months because of the increased air conditioning load on our power plants. The damaging effects of gaseous pollutants commonly are multiplied when particulates are also present in the air.

Some segments of the population are particularly vulnerable to the health effects of air pollution.

The major variables affecting the nature and seriousness of the air pollution problem at any one time and place are . . .

- Types of pollutants
- Quantity of pollutants
- Wind speed and direction
- Topography
- Sunlight
- Precipitation
- Decrease or increase in air temperature with height
- Susceptibility of the individual to particular pollutants or combinations of pollutants

The Pollutants

One of the most common pollutants in urban air is *carbon monoxide*. When this poisonous gas enters the bloodstream, it replaces the oxygen needed to carry on the body's metabolism. At high concentrations it kills quickly; at lower concentrations it brings on headaches and a slowing of physical and mental activity.

Although the burning of any carbon material produces carbon monoxide to some extent, our primary concern is the burning of gasoline in the automobile, and the discharge low to the ground of carbon monoxide from the automobile exhaust. Inside an automobile operating in traffic the concentrations of carbon monoxide may reach high enough levels to affect the driver, thereby creating a safety hazard. At approximately 100 parts of carbon monoxide for every million parts of air most people experience dizziness, headache, lassitude, and other symptoms of poisoning. Concentrations higher than this occasionally occur in garages, in tunnels, or behind automobiles. For example, concentrations of more than 100 parts per million were found occasionally during several months of observations in heavy traffic in Detroit, and in Oxford Circus, London, re-

cent measurements frequently exceeded this figure.

Several factors increase susceptibility to carbon monoxide poisoning. Impairment of circulation, heart disease, anemia, asthma, lung impairment, high temperature, high altitude, and high humidity, all are conductive to making certain persons particularly vulnerable to carbon monoxide exposure. In adopting its "serious" levels of carbon monoxide standards in 1960 the California Department of Public Health indicated that exposure to 30 parts per million of carbon monoxide for eight hours or to 120 parts per million for one hour may be a serious risk to the health of sensitive people. In each of six cities in which the Division of Air Pollution recently measured carbon monoxide inside motor vehicles in traffic, at least ten percent of the samples taken exceeded 30 parts per million, and the averages for the cities ranged from 21 parts per million to 39 parts per million.

Rats exposed to levels of carbon monoxide commonly found in traffic exhibited reduced alertness — exposed animals were not as prone to investigate noises and odors as were animals not so exposed. The carbon monoxide did not seem to impede the animals' ability to receive stimuli, but rather to reduce their ability to integrate the stimuli, and thereby reduce their ability to make appropriate response. The implications of these findings for man are not certain, but the evidence suggests that carbon monoxide may prevent us from responding properly in a complex situation, such as driving in traffic. The effects may be similar to the effects of alcohol or fatigue. In fact, carbon monoxide may be doubly dangerous when a driver is tired, has had an alcoholic beverage, or is under treatment with certain drugs, such as tranquilizers.

The coal and oil that are burned so abundantly all over this country to heat buildings and to generate power contain elemental sulfur as an impurity. When the fuel is burned the sulfur burns too, producing *sulfur dioxide* gas and, to a much smaller extent, *sulfur trioxide*, which in the atmosphere immediately converts to sulfuric acid. Sulfur dioxide gas alone can irritate the upper respiratory tract; adsorbed on particulate matter it can be carried deep into the lung where it can injure delicate tissue. Sulfuric acid in the right particle size can also penetrate deep into the lung and damage tissue.

The evidence is considerable that the *sulfur oxides* family of pollutants aggravates existing respiratory disease in humans and contributes to its development.

In the air pollution disasters described above the levels of sulfur pollution were excessively high, as were levels of other gaseous and particulate pollutants. There are strong indications that those who became severely ill during the Donora and London episodes, were more likely to have poor health subsequently.

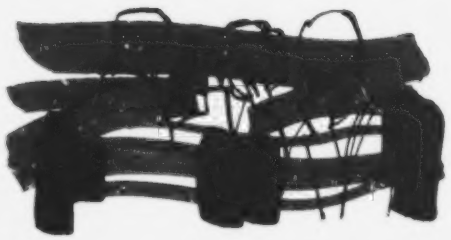
Various investigations have shown that certain portions of the population are especially vulnerable to sulfur pollution. For example: prolonged exposure to relatively low levels of sulfur dioxide has been associated with increased cardiovascular morbidity in older persons; prolonged exposures to higher concentrations of sulfur dioxide has been associated with an increase in respiratory death rates and with an increase in complaints by school children of non-productive cough, mucous membrane irritation, and mucous secretion; the most important single factor affecting the feeling of well-being in chronic bronchitis patients was the level of smoke and sulfur dioxide pollution.

In other studies it was demonstrated that the annual incidence of respiratory disease was directly proportional to the annual sulfur oxides level. As sulfur oxides levels

went up, so too did the incidence of disease. Deaths from respiratory causes have also been found to be more frequent in populations exposed to higher levels of the sulfur oxides. This is not to say that the sulfur oxides alone were responsible for the higher rates; it was probably the combination of the sulfur oxides with other particulate matter that resulted in the higher incidence of disease and premature death.

Photochemical smog is a mixture of gases and particles manufactured by the sun chiefly out of the combustion products of such organic fuels as gasoline. The major components of photochemical smog are oxidizing by nature, and as a class they are called *oxidants*.

The most common effect of oxidants on humans is eye irritation. Although the specific chemical which irritates the eyes has not been completely identified, in general, when the oxidant content of the air reaches a certain level, eye irritation begins. This level—one tenth of a part of oxidant for every million parts of air—is commonly reached in almost every urban area of the country, anywhere from a few days a year to as frequently as a third of the days per year. The frequency depends on many factors, including the amount of sunlight, the



density of the automobile population, and the ability of the local atmosphere to cleanse itself.

Studies have shown that the oxidants at levels routinely found in our cities make it more difficult for people to breathe, especially people already suffering from respiratory disease. For one thing, such exposures produced greater airway resistance in those afflicted with respiratory disease.

One of the oxidants in photochemical smog, *ozone*, can severely irritate mucous membranes. At levels commonly found in our city atmospheres, ozone will irritate the nose and throat after only 10 to 30 minutes exposure. At somewhat higher levels and after slightly longer exposures, ozone produces coughing, choking, and severe fatigue. At relatively high levels, such as those occurring during severe photochemical smogs, ozone will interfere with lung function for the duration of the exposure and beyond. For example, a two hour laboratory exposure of normal subjects to 0.6-0.8 parts per million of ozone markedly reduced lung diffusing capacity, vital capacity, and forced expiratory volume. These effects lasted up to 24 hours in some subjects, and they were accompanied by bronchial irritation, slight coughing, and soreness in the chest.

Other studies have shown that exposure to relatively high levels of ozone considerably reduces visual acuity, and still other studies have shown that chronic occupational exposures to such levels of ozone have produced recurrent headache, fatigue, chest pains, difficulty in breathing, and wheezing.

We do not have very much information on the effects of long term human exposure to ozone, but we do have information on the effects of such exposures on animals. For example, continuous low level ozone exposure for 3 to 17 weeks shortened the lives of infected guinea pigs and increased their death rate, and discontinuous exposure to the same concentration over a period of 3 weeks increased the mortality of newborn mice.

We have only begun to study the effects on humans and laboratory animals of another of the photochemical oxidants, *P.A.N.*,

which is short for peroxyacyl nitrates. We do know that PAN can cause eye irritation, and apparently it has the same effect on human lung function as the overall family of oxidants.

At the temperatures commonly reached when we burn fuels for various purposes, nitrogen in the air combines with oxygen to form *nitric oxide*, which is relatively harmless, but which usually converts in the atmosphere to the more dangerous *nitrogen dioxide*. The rate at which nitric oxide converts to nitrogen dioxide is greatly accelerated by the same conditions which lead to the formation of photochemical smog, and nitrogen dioxide is usually considered to be one of the photochemical oxidants. However, we should keep in mind that nitrogen dioxide is present in the air wherever fuels are burned, and whether or not photochemical smog has been produced.

We have very little information on the effects on man of exposures to the levels of nitrogen dioxide commonly found in polluted air. The odor of the gas is detectable at levels which are sometimes reached in polluted atmospheres—1 to 3 parts of nitrogen dioxide for every million parts of air—but the threshold levels for eye and nose irritation are apparently much higher. In one study only three of eight volunteers reported eye irritation at a concentration of 13 parts per million, although seven of the eight reported nose irritation at this level.

Experiments with animals have shown, in general, that exposures to 10 to 20 parts per million of nitrogen dioxide produce persistent pathologic changes in the lungs. At concentration between 5 and 10 parts per million animals continuously exposed sometimes showed respiratory harm, but animals intermittently exposed to this concentration yielded negative results.

The most sensitive indication that has been found of biological harm from exposure to nitrogen dioxide is increased susceptibility in laboratory animals to infection. In the previously mentioned experiments with mice and pneumonia organisms it was found that animals infected with the bacteria and also continuously exposed to low levels (0.5 to 3.5 parts per million) of nitrogen dioxide died more frequently than animals who were infected, but who were not exposed to the gas.

This relationship between exposure to an irritant gas and increased mortality among infected laboratory animals has profound implications for us in considering what levels of air pollution we should tolerate. If we are to protect the individual who chronically or even temporarily is suffering with disease, we must set much more rigorous standards than if we were to consider only the robust individual.

Whenever we burn something, we almost never burn it completely, and as a result, whenever we burn something, we almost always discharge *hydrocarbons* to the air. There are many sources of hydrocarbon pollution, but by far the major source is the burning of gasoline in the automobile.

Hydrocarbons are a vast family of chemicals most of which are directly harmful only in very high concentrations. However, a number of hydrocarbons at low concentrations will photochemically react in the atmosphere with the nitrogen oxides to produce photochemical smog, discussed previously. The reactions which result in smog are very complex, and not all of them have been identified. However, in general, it can be said that a reduction in hydrocarbons results directly in a reduction in smog, and for this reason one of the major approaches to controlling automotive pollution is the reduction in hydrocarbon emissions from the gasoline engine.

Although most hydrocarbons are not considered directly harmful in the amounts we

find them in polluted air, a considerable number of them have produced cancer in laboratory animals. One of these, thought by many to be a cancer producing substance in cigarette smoke, is commonly found in urban air. One study indicates that, for the average city, breathing city air is the equivalent, in terms of this substance, of smoking seven cigarettes a day. And for the most heavily polluted city, the study indicates that breathing city air is the equivalent of smoking one pack of cigarettes a day.

In the past 20 years a progressive increase in death rate from lung cancer has been reported in many countries. This increase cannot be entirely attributed to improved diagnostic methods or to increased lifespan. A remarkable feature of the report is the consistency of their findings . . .

> The death rate from lung cancer in urban areas is considerably higher than in rural areas.
>
> This difference is not completely explained by the differences in smoking habits.
>
> Certain hydrocarbons may be the cancer producing agents in both cigarette smoke and in polluted air.

Particulates—solid, and occasionally liquid matter—in the air may be large enough that they settle rapidly to the ground, or small enough that they remain suspended in the air until removed by such natural phe-

nomena as rain, and wind, and yes, by people breathing them into their lungs.

Some particulates are directly harmful—they contain poisonous substances or substances, such as the hydrocarbons discussed above, which may cause cancer. Other particulates multiply the potential harm of irritant gases. Sulfur dioxide, for example, is highly soluble in water, and if inhaled by itself will dissolve relatively harmlessly in the upper respiratory tract. But sulfur dioxide is rarely inhaled alone; and sulfur dioxide gas adsorbed on particulate matter will penetrate deep into the lung where it will cause much greater harm.

Still other particulates speed chemical reactions in the atmosphere which may yield much more harmful substances than the ingredients that went into them. For example, certain particulates speed the conversion of sulfur dioxide to sulfuric acid.

Although we do not have extensive studies of the effects of particulates at the levels found in polluted atmosphers, some observations can be made. *Arsenic* is given off, for instance, by copper smelters, and also finds its way into our environment in pesticides. Arsenic, a well-known poison, is suspected of inducing cancer. *Asbestos* fibers have been associated with chronic lung disease, and with cancer of the lung and pleural cavity. The fibers come to us from the wearing away of brake linings, roofing, insulation, and shingles. *Beryllium*, it appears, has produced malignant tumors in monkeys. Beryllium is used in the production of metallic alloys and as a fuel for rocket engines. *Cadmium* is a respiratory poison, and it may contribute to high blood pressure and heart disease. *Fluorides* are discharged to the atmosphere during the manufacture of phosphate fertilizers, the production of aluminum and steel, and during the firing of some rockets. The fluorides have caused severe damage to cattle and to vegetation in certain areas of the country. Fluorosis in cattle results in crippling skeletal changes. *Lead* is a cumulative poison and is taken into the body in water and food as well as in air. Most of the lead in the atmosphere is emitted by motor vehicles burning leaded fuels. Lead can damage the brain of young children and cause death. It can also impair the functioning of the nervous system in adults. Auto exhaust containing lead was found to increase the concentration of lead in the bones of mice.

Air Pollution Obscures Visability.

The most obvious effect of air pollution is the limit it puts on visibility. Most of our major cities are located in natural basins at the confluence of rivers, around bays, or in flat areas backed up by mountains. In many cities these basins are natural traps for any kind of wastes that can hang suspended in the atmosphere. Within their envelopes of haze, our city skylines are sometimes more easily imagined than seen.

Because it reduces visibility, air pollution is a definite hazard to land, water, and air transportation. For example, a review by the Civil Aeronautics Board of 1,660 record cards, representing one-third of the aircraft accidents in the United States in 1962, showed six in which "obstructions to vision" by smoke, haze, sand, or dust were listed as a cause.

The familiar fog, dust, and smoke seemingly have always been around to occasionally obscure our view. In the past few decades some not so familiar materials have increasingly blurred the vision of what we used to see.

Nitrogen dioxide, which peaks during morning rush hour traffic, absorbs light in the blue region of the spectrum, and is responsible for the whiskey brown haze that stains the sky over many of our cities.

The particles that form during photochemical smogs also reduce visibility. Studies have shown that as oxidant levels go up, visibility goes down, sometimes to as low as a quarter of a mile. In Los Angeles, where smoggy days are commonplace, visibility frequently is less than three miles, which is considered the minimum visibility for the safe operation of airplanes.

The sulfur oxides, particularly sulfuric acid mists, scatter light to reduce visibility. It has been found that as relative humidity goes up so does the proportion of sulfuric acid to the other sulfurous pollutants. Therefore, wherever sulfurous pollution is significant, and that is wherever coal and oil are common fuels, we can expect visibility to go down as relative humidity goes up.

Air Pollution Attacks Materials.

Air pollutants abrade, corrode, tarnish, soil, erode, crack, weaken, and discolor materials of all varieties.

Sulfur pollution attacks and destroys even the most durable of materials. Steel corrodes two to four times faster in urban and industrial areas, than it does in rural areas, where much less sulfur-bearing coal and oil are burned. When particulate matter, such as dust, is also present in the air, the corrosion rates multiply. In the city of Pittsburgh, during the period 1926 to 1960, the corrosion of zinc went down by a factor of four as a direct result of a threefold reduction in sulfur pollution and a twofold reduction in dust. It has been estimated that one third of the replacement cost of steel rails in England is attributable to sulfur pollution.

Electrical equipment manufacturers are forced in some cases to use gold for electrical contacts, because other metals such as silver and palladium corrode in sulfur atmospheres, and the corroded metal resists the passage of electric current.

Women in more than one U.S. city with sulfur pollution have had the unfortunate experience of developing runs in their nylons in the time it took them to walk to lunch and back again.

Sulfur pollution at relatively low levels can destroy paint pigments, and at slightly higher levels can attack fresh paint films to delay drying and to produce water sensitivity.

From all over the world it has been reported that the rise in sulfur pollution is accelerating the erosion of stone statuary and buildings, and in many cities conservationists are moving works of art indoors to preserve them. Cleopatra's needle has deteriorated more since its arrival in New York in 1881 than it did during the more than three thousand years it spent in Egypt.

Particulate matter in the air not only accelerates the corrosive action of other pollutants, like the sulfur pollutants, it is largely responsible for the grime of life. We have to clean our clothes, wash our cars, paint our houses, and clean our buildings more and more frequently because of the quantities of particulates that puff from our chimneys.

The principal component of photochemical smog, ozone, damages textiles and discolors dyes. Ozone greatly accelerates the cracking of rubber. Stressed rubber has cracked after less than an hour's exposure to ozone in concentrations lower than those commonly reached in metropolitan areas.

Air Pollution Injures and Kills Plants.

One of the most widespread effects of polluted air is damage and destruction to vegetation. Indeed, many plants are more sensitive to air pollution than are humans and animals, and are used as indicators of the presence of harmful contaminants.

Air pollution now places very real restrictions on the types of vegetation that may be raised in many areas of the country. In the metropolitan areas of California, for example, photochemical smog has made it impossible to raise orchids, and the growers have had to relocate in remote, rural areas. In the Garden State of New Jersey, pollution injury to vegetation has been observed in every single county, and damage has been reported to at least 36 commercial crops, including spinach, endive, romaine, table beets, and chicory. In central and southern Florida, orange trees have been severely damaged, causing some growers to relocate. Indeed, virtually every urban area in the nation now experiences damage to vegetation from air pollution, and many rural areas that once were thought to be safely re-

moved from pollution sources are now experiencing crop injury.

More and more park superintendents are reporting that they are becoming increasingly limited in what they can grow. So too are plant lovers and gardeners realizing that they must often limit the types of plants they wish to cultivate to those that are less susceptible to polluted air. With increasing frequency gardeners are experiencing damage and destruction to such common and desirable ornamentals as petunia, snapdragon, chrysanthemum, larkspur, carnation, orchid, pansy, rose, and zinnia.

The most dramatic destruction of vegetation by air pollution has taken place in the vicinity of smelters discharging large amounts of sulfur pollution to the atmosphere. In 1910 and 1911 all of the major tree species were dead or dying in a 5 to 8 mile radius from a smelter at Anaconda, Montana. In the vicinity of the Trail, British Columbia, smelter, which in 1929 emitted an average of 18,000 tons of sulfur pollution per month, plant injury was observed as far as 52 miles from the smelter. Sixty to 100 percent injury to Douglas fir, ponderosa pine, and forest shrubs occurred as far as 30 miles from the smelter in a river valley. Even though control devices were installed in 1934, by 1936 more than 80 percent of the pines that were alive in the valley had no cones.

These plant disasters are certainly disturbing, but what is even more disturbing is the fact that at levels routinely observed in some of our cities, many plants are damaged by sulfur pollution. Generally, the plants most sensitive to sulfur pollution are those with succulent leaves having high physiological activity — plants such as alfalfa, the grains, squash, cotton, grapes, white pine, apple, and endive. Plants with a heavy waxy leaf such as citrus and privet are more resistant to sulfur pollution. High light intensity (especially in the morning hours), high relative humidity, adequate moisture supply, and moderate temperature — ironically, all those things which cause the plant to thrive — predispose the plant to injury.

The visible markings of sulfur pollution on vegetation frequently serve notice of damage. Acute exposure of broad-leafed plants to sulfur dioxide causes areas of the leaves to die, dry out, and usually bleach to a light tan or ivory color. Damage to grasses is similar except that the pattern is more a streaking along the blade, and frequently, the tip is killed. The needle-shaped leaves of pine and fir trees begin to die at the needle tip.

There is, however, another form of sulfur dioxide injury that is very difficult to identify in the field. Plants exposed to sulfur dioxide concentrations that do not produce characteristic acute injury may develop a chronic type of injury. Generally, the symptom of chronic injury is a yellowing of the older leaves. This symptom is frequently described as early aging. Analysis of leaf tissue often helps identify this type of hidden injury.

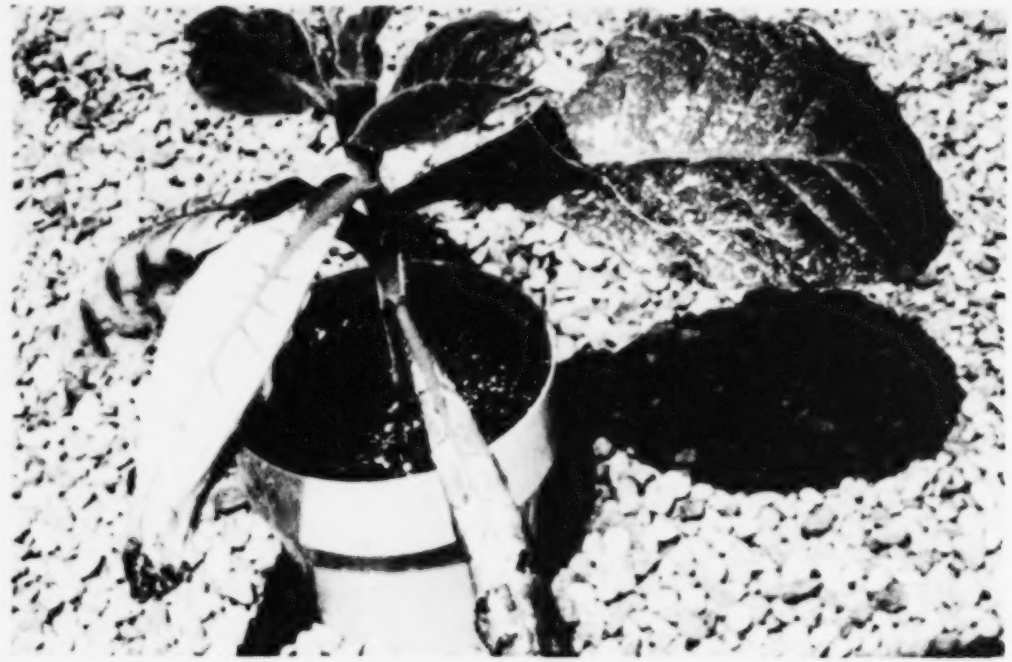
Another pollutant, nitrogen dioxide, produces injury symptoms similar to those caused by sulfur dioxide. Furthermore, scientists are just now finding out that nitrogen dioxide seems to restrict the growth of plants without their showing any characteristic symptoms of injury.

Another pollutant that produces a characteristic injury pattern on plants is fluoride, which is emitted during the industrial processing of fertilizers, aluminum, and steel, for example. On most broad-leafed plants fluoride causes tissue to die at the edge and tip of the leaf. The dead tissue dries out, usually turns brown, and may fall off leaving a ragged edge. On the grasses the blade dies from the tip. On the needle-leaved

trees the injury is very similar to that caused by sulfur dioxide.

Fluoride injury results from accumulation of fluoride in the tissue of plants. An analysis of the leaf tissue for fluoride is usually excellent confirmatory evidence of fluoride injury. The sensitivity of different plants to damage by fluoride varies greatly. Some plants can accumulate very high concentrations of fluoride and show no injury, whereas other plants, such as gladiolus, can accumulate injurious amounts from an atmosphere that contains only traces of fluoride. Gladiolus, pine, apricot, prune, and azalea are very sensitive to fluoride damage.

The great economic significance of ozone damage to plants was not recognized until as recently as 1958, when it was found in California that lesions in grape leaves could be produced by a 3-hour fumigation to as little as half a part of ozone per million parts of air. Tobacco too is sensitive to ozone, so much so that tobacco plants are increasingly used to measure levels of ozone. Ozone is now recognized as a major threat to leafy vegetables, field and forage crops, shrubs, fruit and forest trees — particularly conifers. One review of ozone damage to plants lists 57 different species that have been reported susceptible to ozone injury. The typical



ozone pattern of injury is flecking or stippling of the upper surface of leaves. These spots are small clusters of dead cells. We are uncertain why ozone kills these cells and not others.

PAN, another of the oxidants in photochemical smog, is extremely toxic to many species of field crops — spinach, beets, celery, tobacco, pepper, endive, Romaine lettuce, swiss chard, and alfalfa — and to several ornamentals — petunia, snapdragon, primrose, asters, and fuchia. Woody shrubs and trees and some field crops — grape, cabbage, and onions — are relatively resistant to PAN.

The classic photochemical smog pattern of injury is a glazing or silvering of the undersurface of leaves. Cells collapse and leave the epidermis slightly separated from the cells. The color of injured leaves varies from silver to bronze, depending on pigment development. Eventually, the tissue dries leaving blotchy, dead areas on the undersurface, and sometimes through the leaves.

Under controlled conditions auto exhaust exposed to ultraviolet light, simulating photochemical smog conditions, has produced characteristic smog injury in plants. Some of the injuries were attributable to ozone and others to PAN. Still other injury

patterns indicate that irradiated auto exhaust contains several other unidentified pollutants harmful to plants.

Photochemical smog has caused a serious decline in citrus and "salad" crops in the Los Angeles area, and has seriously damaged ornamentals there. But smog, which was once a joke on Los Angeles, is no longer confined to that area. The entire eastern seaboard, from Boston to Washington, D. C., now suffers agricultural losses due to smog that are on the same scale as those suffered in so[illegible]n California.

Air Pollution Hits Us Squarely in the Pocketbook.

Most often overlooked in any catalog of the money losses chargeable to air pollution is the enormous wastage of fuel and sacrifices of efficiency associated with it. Yet in cold dollars and cents, this is probably the costliest of all the economic effects of air pollution. Whenever we see a dense black plume rising from a chimney or jetting from the exhaust pipe of a motor vehicle, it is prima facie evidence of incomplete combustion. The fuel is not providing its full measure of heat or power. Considering that not only every factory and powerplant and every motor vehicle but also the heating of every home and store and public building contribute to the total, the annual dollar cost to the Nation in wasted fuel alone undoubtedly runs into the billions. At today's prices, the wastage of the sulfur found as an impurity in most fuels, alone costs us $300 million per year.

Reduction of visibility and sunlight is another economic waste. It has been reported, for example, that Chicago's sunlight is reduced by 40 percent because of air pollution. Beside increasing lighting bills and making transportation hazardous, darkness in daylight generates gloom.

Agricultural losses from air pollution, including damages to livestock, growing crops, and other plants and trees, are estimated at approximately $500 million a year. While this may be no more than 4 or 5 percent of the total economic damage attributed to contaminated air, it deserves emphasis for at least two reasons: (1) until recently, air pollution has been thought of, and dealt with — or ignored — by many lawmaking bodies as if it were exclusively an urban problem; and (2) evidence of its harmful effects on more and more kinds of vegetation and in more and more localities is accumulating with exceptional rapidity.

As indicated earlier, air pollution also accelerates the deterioration of materials, structures, and machines of all kinds. This, in turn, greatly increases maintenance and replacement costs. Metals corrode, fabrics weaken and fade, leather weakens and becomes brittle, rubber cracks and loses its elasticity, paint discolors, concrete and building stone discolor and erode, glass is etched, and paper becomes brittle. Even when only soiling of materials is involved, the removal of the deposited grime is often costly and shortens the life of the materials.

Estimates of economic losses due to air pollution are often overly conservative. Rarely are the costs identified for using expensive materials that are resistant to pollutants in place of cheaper materials that would be satisfactory in clean air. As mentioned before, gold and other precious metals are widely used for electrical contacts because of their low chemical reactivity. The present cost of gold used annually in the United States for electrical contacts is approximately $15 million. If silver could replace gold, the savings would be $14.8 million, based on equivalent volumes of metal.

The cost of replacing or protecting precision instruments and other equipment affected by pollutants is great and growing. The complex and expensive control systems which are becoming so commonplace in modern technology can be ruined or seriously damaged by the corrosive action of gaseous pollutants or by deposited dust. To prevent such damage, many industries — for example, those manufacturing high-precision components for telecommunication of space vehicles — must clean, at considerable expense, air admitted to plants. So too must many makers of foods, confections, beverages, and other goods for which the utmost cleanliness is a requisite.

While exact data are not available on the full extent and total cost of air pollution's damage to property, various cost estimates have been made. The one most frequently used is $65 per capita per year — an annual cost to the Nation of over $12 billion.

To control air pollution, the economic costs of which by themselves run into the billions, government and industry are together spending only millions. When we consider the priceless benefits of clean air to our health, surely the adequate control of air pollution is a bargain.

national conference on air pollution

December 12-14, 1966
Washington, D. C.

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PUBLIC HEALTH SERVICE
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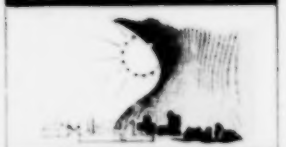

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